ENVIRONMENTAL HEALTH PROJECT

ACTIVITY REPORT

No. 43

Rehabilitation of Priority Springs and Wells
in Jordan

Part I: Assessment Report on
Wadi Sir, Qairawan, Qantara, and Deek/Teis Springs
and Kafrein Wells

December 1997

by
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Prepared for the USAID Mission to Jordan
under EHP Activity No. 423-CC

Environmental Health Project
Contract No. HRN-C-00-93-00036-11, Project No. 936-5994
is sponsored by the Bureau for Global Programs, Field Support and Research
Office of Health and Nutrition
U.S. Agency for International Development
Washington, DC 20523

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Abbreviations and Symbols

Camp Dresser & McKee International	CDM
Commerce Business Daily	CBD
cubic meter per hour	m^3/hr
Environmental Health Project	EHP
Jordan Valley Authority	JVA
Kilo Volt Ampere	KVA
kilometer	km
milligrams per liter	mg/l
millimeter	mm
Ministry of Health	MOH
Most Probable Number per 100 milliliters	MPN/100 ml
United States Agency for International Development	USAID
Water Authority of Jordan	WAJ
Water Quality Improvement and Conservation Project	WQIC
Water Treatment Plant	WTP

About the Authors

Janelle Daane, P.E., is an environmental, civil, and construction engineer, with over 15 years' experience developing water supply and sanitation services, primarily for indigenous people. She has worked extensively in the former Soviet Union where she helped lead USAID assistance programs to address environmental damage to the Aral Sea, water supply needs for repatriating ethnic groups in Crimea, and water utility reform in Ukraine. Dr. Daane is versed in disaster assistance work and provision of fast-track water and wastewater services in Africa and the Middle East. As a field engineer, she worked in native Alaskan villages to provide rural water and wastewater services for the U.S. Public Health Service. Currently, she manages international engineering, disaster assistance, and demand-driven pollution reduction contracts for Camp Dresser & McKee International.

Frederick J. McNeill, an environmental engineer, has over 15 years of experience in the design, management, and construction of water and wastewater facilities. For the past 13 years Mr. McNeill has worked with Camp Dresser & McKee, the past 10 years in its International Division. He has worked on water and wastewater projects in Egypt, Oman, Jordan, Gaza, Armenia, Georgia, and Bulgaria. For several years Mr. McNeill was involved in the design and construction of the Greater Cairo Wastewater Project in Egypt which was, at the time, the largest wastewater project in the world. Recently, he served as project manager for the design of new water and wastewater facilities in Wadi Mousa, Jordan. Before joining Camp Dresser & McKee, Mr. McNeill served as a Peace Corps Volunteer in Sierra Leone where he managed a rural water supply project.

Chapter 1
Introduction

Jordan is an arid to semi-arid country, with a land area of approximately 96,000 km^2. The capital, Amman, is a city of 1.6 million people located in the northwest portion of the country. More than 90% of the land area of Jordan receives less than 200 mm of rain per year, and approximately 85% of the total average rainfall is lost to evaporation. The remaining portion recharges groundwate r and contributes to river and wadi flows.

In many Jordanian cities, residents receive water only sporadically. The figure for average domestic water consumption, under 100 liters/capita/ day, is one of the lowest in the world. Water scarcity is exacerbated by rapid population growth, inadequate water management, and inefficient use. The most feasible options for reducing the gap between water demand and supply are improved management of existing water resources, treatment of wastewater for reuse, and rehabilitation of existing water sources.

This project will consist of the installation of package treatment plants at four contaminated springs and provide a design for a new water source being developed by the Water Authority of Jordan (WAJ). Using a design/build process, equipment, technical assistance, and training will be provided for the rehabilitation of four priority springs to serve as drinking water sources for communities in Jordan.

The project has been divided into two parts. Part I consists of full rehabilitation of the Qairawan, Deek/Teis, Qantara, and Wadi Sir springs and development of an engineering design for the Kafrein wells (see Figure 1-1, Location Map). Rehabilitation of the four priority springs will include site assessment, environmental evaluation, appropriate technology selection, design, site preparation, installation of package treatment units, and operation and maintenance services. The engineering design for the Kafrein wells will include site assessment, environmental evaluation, appropriate technology selection, and design of delivery piping from the wells to the treatment unit and reservoir. The Kafrein design will be based on demand information provided by the WAJ. Conventional tender documents will be produced for the Kafrein water system and submitted to the WAJ.

Part II of the project consists of the rehabilitation of five other springs and wells to serve as drinking water sources for residents of Jordan. These sources are considered less urgent and will be addressed under a separate assessment scheduled to be conducted in February 1998.

Figure 1-1

Treatment of water from the Qairawan, Deek/Teis, Qantara, and Wadi Sir springs is urgently needed. Because of high bacterial levels during the summer season, the Ministry of Health (MOH) has required that these water sources be shut down. As a result, many residents in the distribution zones of each spring receive water from other zones only once every 10 to 14 days. To make up for the shortage of water, vendors have been delivering water to residents in tanker trucks. Unfortunately, many vendors have been observed filling their trucks with water from the contaminated springs and selling it to residents.

The loss of these sources for potable water has imposed extreme hardship and increased the health risks of approximately 125,000 residents. To get these contaminated water sources rehabilitated by the next dry season, WAJ has asked the United States Agency for International Development (USAID) to provide emergency assistance. Due to the urgent need for drinking water in these locations and to meet the aggressive schedule necessary to begin installation of the water treatment plants (WTPs), USAID has authorized limited competition for procurement of the package treatment units and the subcontract for site preparation work.

This report presents the site assessments, evaluates and recommends treatment technologies, assesses environmental effects associated with each proposed technology, and describes a project implementation plan. Limitations to this report include the short time frame to: collect water quality data, gather site information, synthesize this information, correspond with vendors, select appropriate technology, and generate the report.

Chapter 2 covers the engineering site assessment for each of the four priority spring water sources and the Kafrein wells. A description of the water quality and quantity, an assessment of primary contaminants, and determination of civil, mechanical, and electrical requirements are provided in the discussion for each site.

Chapter 3 describes the recommended treatment technologies for each site. Environmental impacts associated with the proposed method of treatment, including spring production capabilities, water demand, consumption patterns, wastewater production, and archeological considerations are discussed in Chapter 4. The project implementation plan is outlined in Chapter 5. Recommendations for the sequence of site installations, a fast-track schedule for completing the installations, and preferred contracting mechanism are also provided in that chapter. Chapter 6 includes a brief description of recommended rehabilitation and maintenance measures and issues related to the installation of the package treatment plants which need to be addressed in the near future.

Chapter 2
Site Assessments

To address the emergency need for drinking water, WAJ asked USAID to provide package water treatment units at four springs and a water conveyance and treatment system design for a newly developed well-field site by May 1998. To meet this schedule, site assessments were conducted in early November 1997 at each of the four spring water sources and the Kafrein Wells. This chapter describes the findings of those assessments, specifically water quality and quantity information associated with each site, primary water contaminants, and civil, mechanical, and electrical details that must be considered for installation of package treatment plants.

2.1 Wadi Sir Spring

The Wadi Sir spring is located in southwestern Amman and has historically produced drinking water for the community of Wadi Sir. The Amman aquifer and Wadi Sir aquifer together produce water for the Wadi Sir spring since they are hydraulically connected. The Wadi Sir spring discharges from the northern end of the Wadi Sir aquifer. Water from the spring is collected in a closed concrete reservoir constructed along the side of the wadi. Water from the reservoir flows by gravity to a pump station on the opposite side of the wadi, where it is pumped to (1) a reservoir which serves the community of Wadi Sir, (2) the Al Hussein Medical City reservoir which serves a medical community, and (3) other distribution networks in Amman.

A site plan of the Wadi Sir spring and existing pump station facility are shown in Figure 2-1, and site pictures are shown on page 2-3.

Figure 2-1
Wadi Sir - Existing Pump Station Facility

Photo 1: Wadi Sir Spring

Photo 2: Wadi Sir Pump Station

2.1.1 Water Quality and Primary Sources of Contamination

Water quality information on the Wadi Sir spring is provided in Table 1. This information has been compiled from a report prepared through the Water Quality Improvement and Conservation (WQIC) Project, analytical laboratory results produced by the WAJ Laboratories and Quality Control Department, and laboratory results produced by CDM International Laboratories in Cambridge, Massachusetts. The CDM water quality results are based on only one sample taken during site assessments. CDM water quality results are shown in parentheses where no data were available from WAJ laboratories or, in a few cases, where there were slight discrepencies between CDM and WAJ laboratory values. Other CDM test results agreed with local laboratory results and so are not shown.

TABLE 1
Water Quality-Wadi Sir Spring

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	75-85	80	no standard	no standard
Magnesium (Mg)	59-69	65	no standard	no standard
Total Hardness ($CaCO_3$)	430-496	467	100	500
Nitrate (as NO_3)	34-49	39	45	70 in the absence of other water sources
Color	No data	(5.0)	10 units	15 units
Iron $(Fe)^{+3}$ dissolved	<0.01	<0.01	0.3	1.0
Manganese (Mn)	<0.01	<0.01	0.1	0.2
Turbidity	0-25	0.5 (0.37)	1 unit	5 units
TSS	0.5-4	(<4.0)	none	none
TDS	411-605	(400)	500	1,500
TOC	No data	(0.67)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml
Fecal Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml

According to the WAJ water quality staff and results shown in Table 1, primary contamination in the Wadi Sir spring is from bacteria. Although the Wadi Sir spring is currently being used to supply water to the hospital and other areas in Amman, in October 1997 the MOH required its temporary closure based on high fecal coliform counts. WAJ staff indicate that it is MOH policy to shut down any water source when its fecal coliform count (before chlorination) is greater than 25 MPN, unless additional treatment facilities exist. Because no coliform were found in samples in past years, MOH and WAJ believe that the presence of coliform indicates that spring water is being influenced by surface water sources, wastewater leaking from sewers, and pathogens that are often present in surface water including bacteria, viruses, crypotosporidia, and giardia. WAJ staff have specifically asked for installation of package units which include ultrafiltration.

2.1.2 Quantity

Information on the quantity of water produced by the Wadi Sir spring has been compiled through the WQIC. This information is included in Appendix B. Information on flows recorded from November 1937 to August 1996 (59 years) indicates maximum and minimum flow rates of 2,950 m^3/ hr and 40 m^3/ hr respectively. The frequency of measurements, shown in Figure 2-2, illustrates that the most frequent flow is approximately 250 m^3/ hr, and the most frequent flow range is approximately 200-500 m^3/ hr.

Figure 2-2

Data provided by WAJ covering the past five years indicate that an annual average of 400 m^3/ hr has been produced by the Wadi Sir spring, with a summer average of 350 m^3/ hr and a winter average of 500 m^3/ hr. The proposed average design flow for the Wadi Sir WTP is 400 m^3/hr.

2.1.3 Site Civil and Mechanical Requirements

- Six pumps exist at the Wadi Sir pump station, four duty and two standby. As mentioned earlier, these pumps deliver water through three distribution lines to the Al Hussein Medical City, Wadi Sir, and the Amman city distribution system. The four duty pumps are rated at a maximum of 566 m^3/hr, and H=325 meters.

- Currently, one of the existing pumps is not in working condition. WAJ staff indicate that this pump can be removed, and a package WTP could be erected in its place. This pump is located in the southern end of the pump room.

- An underground concrete water reservoir—its roof is at the same elevation as the pump house floor—is not sealed. Six piped pump suction inlets and their access hatches along the north side of the reservoir will need to be sealed with concrete to adequately protect treated water.

- Depending on the interior condition of the existing reservoir, a coating suitable for potable water should be used to coat the floor, walls, and ceiling.

- To supply water to the package WTP, it will be necessary to create a raw water wet-well by partitioning off a small portion of the existing reservoir with a double concrete wall. Piped connections will need to be installed in the concrete wall for use during filter bypass.

- A steel pipe overflow and drain will have to be installed in the newly created raw water reservoir.

- To disinfect treated water, the chlorination diffuser needs to be relocated to the finish water reservoir.

- Temporary measures, such as bypass piping and chlorination, may need to be taken during construction so that potable water can still be supplied.

- Discharge piping from the package WTP must be connected to the finish water reservoir.

- It will be necessary to install three pumps, two duty and one standby, with pump pedestals, suction piping, and valving to pump water from the raw water wet well to the package WTP.

- The backwash pump is expected to be provided as part of the WTP. Approximately 35 m of welded steel backwash discharge piping will need to be installed to the nearby sewer collector.

2.1.4 Site Electrical Requirements

- A 1000 KVA transformer is in service, located adjacent to the pump station entrance. Available power is rated at 380 volt, 50 hertz.

- The existing transformer is insufficient for the current electrical demands of the pump station. A new 1500 KVA transformer will be required to provide electrical power to the new WTP suction pumps and backwash pump.

- Approximately 60 m of electrical wire will be needed to connect the package unit and circuit breaker.

- A new distribution board for the new equipment will be required.

- WTP and pump controls will be combined in a single control panel adjacent to the new equipment.

- Outdoor lighting and electrical receptacles should be provided in the WTP, pump, and reservoir areas.

2.1.5 Land Ownership and Space Constraints

- All existing facilities are within the land and property boundary owned by WAJ.

- No additional space or new land acquisition is expected to be required.

- If the existing inoperative pump is removed, approximately 100 m^2 will be available for the WTP.

2.1.6 Cultural Heritage Consideration of Construction Materials

The pump house building is constructed of reinforced concrete walls with stone blocks on the facade. Installation of the package WTP will not impact the outside appearance of the existing pump house.

2.2 Qairawan Spring

The Qairawan spring is located northwest of Amman in the city of Jerash. The spring is located immediately northeast of the Jerash archaeological site and is directly across the street from the Ya Hala restaurant. The spring is in an urban area on the east side of the Wadi Ad Dayr. Groundwater discharging from the Qairawan spring is from the Naur Aquifer. Water from the spring is collected in a large gravel-bottomed pool which is mostly enclosed by concrete walls and a concrete roof. The enclosure is accessible by foot traffic. Chlorine is injected into water collected in the large gravel-bottomed pool. Water from the pool is pumped (1) directly to the distribution network of Al Saru area near Jerash, (2) to an old reservoir which serves part of Jerash, and (3) a new reservoir which also serves water distribution networks in Jerash.

A site plan of the Qairawan spring and existing pump station facility are shown in Figure 2-3, and site pictures are shown on page 2-12.

Figure 2-3

Photo 3: Qairawan Spring

Photo 4: Qairawan Pump Station

2.2.1 Water Quality and Primary Sources of Contamination

Water quality information for the Qairawan spring is provided in Table 2. This information has been compiled from a report prepared through the WQIC analytical laboratory results produced by the WAJ Laboratories and Quality Control Department, and laboratory results produced by CDM International Laboratories in Cambridge, Massachusetts. The CDM water quality results are based on only one sample taken during site assessments. CDM water quality results are shown in parentheses where no data were available from WAJ laboratories or, in a few cases, where there were slight discrepencies between CDM and WAJ laboratory values. Other CDM test results agreed with local laboratory results and so are not shown.

TABLE 2
Water Quality-Qairawan Spring

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	74-99	89	no standard	no standard
Magnesium (Mg)	23-81	43	no standard	no standard
Total Hardness (CaC03)	349-581	399	100	500
Nitrate (as NO3)	27-74	42	45	70 in the absence of other sources
Color	No data	(5.0)	10 units	15 units
Iron (Fe)$^{+3}$ dissolved	No data	<0.01	0.3	1.0
Manganese (Mn)	No data	<0.01	0.1	0.2
Turbidity	0.1-5.4	0.1 (0.09)	1 unit	5 units
TSS	No data	(<4.0)	none	none
TDS	403-832	(390)	500	1,500
TOC	No data	(0.49)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml
Fecal Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml

According to the WAJ water quality staff and data shown in Table 2, primary contaminants in the Qairawan spring occur from bacteria. Currently, this water source is on-line and being used to supply water to Jerash. However, when fecal coliform counts are greater than 25 MPN per 100 ml, as happens often, this source is shut down to comply with MOH regulations.

2.2.2 Quantity

According to information compiled by the WQIC Project, the maximum and minimum discharges recorded from April 1938 through September 1996 were 359 m^3/hr and 60 m^3/hr, respectively. This data is included in Appendix B. The frequency of flow measurements, illustrated graphically in Figure 2-4, shows that the most frequent flow is 125 m^3/hr, and the most frequent flow range is approximately 85 to 200 m^3/hr.

Figure 2-4

Data for the last five years provided by WAJ indicate that an annual average of 150 m^3/ hr has been produced by the Qairawan Spring, with a summer average of 120 m^3/ hr and a winter average of 170 m^3/ hr. The proposed average design flow for the Qairawan WTP is 150 m^3/hr.

2.2.3 *Site Civil and Mechanical Requirements*

- Four pumps exist at the Qairawan pump station, three as duty pumps and one as standby. All pumps connect to one header pipe which supplies three distribution lines. As mentioned above, one line supplies water directly to the network of Al Saru area near Jerash; the other two lines supply an old reservoir and a new reservoir. Three pumps are rated at Q=86 m^3/ hr, and H=145 meters. The fourth pump is rated at 60 m^3/ hr, and H=125 meters.

- Because a raw water wet well is necessary to feed the WTP, a 200 m^3 reservoir for 1.3 hour storage capacity should be constructed. For this capacity, the reservoir should have a base of 6 x 6 meters.

- It will be necessary to install a duty and standby pump, suction piping, valving, and pump pedestals to pump water from the existing spring wet well to the package WTP.

- Discharge piping will need to be installed from the pump to the package WTP to provide sufficient operating pressure for the package treatment plant.

- Discharge piping from the package WTP must be connected to the reservoir.

- To disinfect treated water, new chlorination piping will need to be rerouted to the new reservoir. Existing chlorination piping to the spring wet well will be retained.

- Discharge piping will need to be installed from the reservoir to the suction side of the four existing distribution pumps and will be connected to a new single-header pipe. The benefit of this arrangement is that the old system will be tied into this header pipe to allow the WTP to be taken off line if required.

- It is recommended that the WTP be located in an existing roofless room in the rear of the pump station compound. Currently, the roofless room flooring is at two elevations; thus, minor excavation may be necessary to bring the area to a uniform ground elevation. Roofing will need to be constructed over the two rooms.

- The backwash pump is expected to be provided as part of the WTP. Approximately 40 m of backwash discharge piping will need to be installed to the nearest sewer collector.

2.2.4 Site Electrical Requirements

- A transformer is installed on grade within the pumphouse compound. Available power from the transformer is 630 KVA. The current demand on the transformer from the four pumps is 210 KVA. There should be sufficient surplus power from the existing transformer to operate all new equipment.
- Existing distribution pumps are rated at 380 volt, 50 hertz.
- Approximately 40 m of electrical wire will be needed to connect the package unit and circuit breaker.
- Installation of a new distribution board for the new equipment will be required.
- WTP and pump controls will be combined in a single control panel adjacent to the new equipment.
- Outdoor lighting and electrical receptacles should be provided in the WTP, pump, and reservoir areas.

2.2.5 Land Ownership and Space Constraints

- All existing facilities are within the property boundaries of land owned by WAJ.
- No additional space or land acquisition is expected to be required. Sufficient space appears to be available near the front parking area for construction of the reservoir.
- An existing mobile office on metal skids will need to be removed to allow room for construction of a new reservoir.

2.2.6 Cultural Heritage Consideration of Construction Materials

- The pumphouse building is constructed of reinforced concrete walls with stone blocks on the facade. Installation of the package WTP will not impact the outside appearance of the existing pumphouse.
- The reservoir will be constructed of reinforced concrete. The facade will be covered with local stone facing, consistent with local architecture.

2.3 Qantara Spring

The Qantara spring is located on a rural hillside, east of the Ajlun castle and two km from the community of Ajlun in northwest Jordan. Groundwater discharging from the spring is produced from the Hummar Aquifer and possibly the Naur Aquifer. Spring water is captured from the hillside in a narrow rectangular concrete structure. Water from this structure flows approximately 80 m downhill through a buried concrete channel to a partially underground concrete reservoir. Water from the reservoir is pumped to the communities of Ajlun and Kufrangeh.

A site plan of the Qantara spring and existing pump station facility is shown in Figure 2-5, and site pictures are shown page 2-21.

Figure 2-5

Photo 5: Qantara Pump Station

Photo 6: Qantara Water Users

2.3.1 Water Quality and Primary Sources of Contamination

Water quality information on the Qantara spring is provided in Table 3. This information has been compiled from a report prepared through the WQIC Project, analytical laboratory results produced by the WAJ Laboratories and Quality Control Department, and laboratory results produced by CDM International Laboratories in Cambridge, Massachusetts. The CDM water quality results are based on only one sample taken during site assessments. CDM water quality results are shown in parentheses where no data was available from WAJ laboratories or, in a few cases, where there were slight discrepencies between CDM and WAJ laboratory values. Other CDM test results agreed with local laboratory results and so are not shown.

TABLE 3
Water Quality-Qantara Spring

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	51-104	94	no standard	no standard
Magnesium (Mg)	10-80	31	no standard	no standard
Total Hardness ($CaCO_3$)	168-589	362	100	500
Nitrate (as NO_3)	15-184	42	45	70 in the absence of other water sources
Color	No data	(5.0)	10 units	15 units
Iron $(Fe)^{+3}$ dissolved	No data	<0.01	0.3	1.0
Manganese (Mn)	No data	<0.01	0.1	0.2
Turbidity	0.0-7.7	0.50 (0.51)	1 unit	5 units
TSS	No data	(<4.0)	none	none
TDS	422-625	(400)	500	1,500
TOC	No data	(1.3)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml
Fecal Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml

According to the WAJ water quality staff and data shown in Table 3, primary contamination in the Qantara spring is from bacteria, possibly from cesspits located in the upper watershed. As a result, the Qantara spring has been shut down.

2.3.2 Quantity

Data on the quantity of water produced by the Qantara spring has been collected through the WQIC Project. This data has been collected from June 1938 to September 1996 (with some years missing) and is included in Appendix B. Maximum and minimum flows rates for Qantara are 335 m^3/hr and 10 m^3/hr. The frequency of measurements, shown in Figure 2-6, indicates that the most frequent flow is 110 m^3/hr, and the most frequent flow range is approximately 50 to 225 m^3/hr.

Figure 2-6

Data for the last five years, provided by WAJ, indicate that an annual average of 120 m^3/ hr has been produced by the Qantara spring, with a summer average of 100 m^3/ hr and a winter average of 150 m^3/ hr. The proposed average design flow for the Qantara WTP is 150 m^3/hr.

2.3.3 Site Civil and Mechanical Requirements

- Two pumps exist at the Qantara pump station. All pumps connect to one header pipe which supplies two distribution lines for Ajlun and Kufrangeh. One pump is rated at Q=80 m^3/hr and H=230 meters; the other is rated at a 100 m^3/hr and H=250 meters.

- Because piped water from a raw water wet well is needed to feed the WTP, a below-grade wet well should be built adjacent to the buried concrete channel feeding the reservoir.

- It will be necessary to install three pumps—two duty and one standby, suction piping, valving, and pump pedestals to pump water from the proposed wet well to the package WTP.

- Discharge piping will need to be installed from the pump to the package WTP to provide sufficient operating pressure for the package treatment plant.

- Discharge piping from the package WTP must be connected to the existing below-grade channel that connects to the existing reservoir.

- The WTP should be located on a new reinforced concrete slab on grade adjacent to the existing pump station. The WTP and pumps would be covered by a steel sunscreen.

- The backwash pump is expected to be provided as part of the WTP. Approximately 50 m of backwash discharge piping will need to be installed to the nearby wadi.

2.3.4 Site Electrical Requirements

- A pole-mounted transformer is installed near the rear of the pumphouse compound. Available power is rated 400 KVA. The current demand on the transformer from two pumps is 240 KW. It appears that this transformer will be able to serve the WTP equipment.

- Existing distribution pumps are rated at 380 volt, 50 hertz.

- Approximately 40 m of electrical wire will be needed to connect the package unit and circuit breaker.

- Installation of a new distribution board will be required for the new equipment.

- WTP and pump controls will be combined in a single control panel adjacent to the new equipment.

- Outside lighting and electrical recepticles should be provided in the WTP area.

2.3.5 Land Ownership and Space Constraints

- All existing facilities are within the property boundaries and land owned by WAJ.

- No additional space or new land acquisition is expected to be required. All equipment can be installed within the existing pump station boundary walls.

2.3.6 Cultural Heritage Consideration of Construction Materials

- The pumphouse building is constructed of reinforced concrete walls with stone blocks on the facade. Installation of the package WTP will not impact the outside appearance of the pumphouse.

2.4 Deek/Teis Springs

The Deek and Teis springs are located approximately five km southwest of the city of Jerash. The springs are located on opposite hillsides on the Wadi Nahla-Wadi Tawahna. The spring area is vegetated with trees and brush and is located upgradient of several small villages including Al Kitta, Nahla, Raymun, and Sakib. Groundwater discharging from both springs originates from the Naur Aquifer.

A concrete box is erected over the mouth of the the Deek spring. The box is lined with gravel. Animal feces were observed in several areas within the concrete box. Groundwater flows from two sources along the gravel-bottomed box and into a pipe which carries water to a reservoir approximately 150 m downhill.

Water from the Teis spring flows out of a hillside and along the side of the wadi. A sealed concrete box erected next to the mouth of the spring captures some of the spring water. Water from this concrete box is piped to the same reservoir as water from the Deek spring. The water collected in the reservoir is chlorinated in the pump station discharge line and then pumped to (1) the Gaza refugee camp, (2) the Debein area, and (3) the village of Kitta.

A site plan of the Deek/Teis pump station is shown in Figure 2-7 and site pictures are shown on page 2-29.

Figure 2-7

Photo 7: Deek Spring

Photo 8: Deek Pump Station

2.4.1 Water Quality and Primary Sources of Contamination

Water quality information on the mixed water from the Deek and Teis springs is provided in Table 4. This information has been compiled from analytical laboratory results produced by the WAJ Laboratories and Quality Control Department, and laboratory results produced by CDM International Laboratories in Cambridge, Massachusetts. The CDM water quality results are based on only one sample taken during site assessments. CDM water quality results are shown in parentheses where no data was available from WAJ laboratories or, in a few cases, where there were slight discrepencies between CDM and WAJ laboratory values. Other CDM test results agreed with local laboratory results and so are not shown.

TABLE 4
Water Quality-Deek/Teis Springs Mixed

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	51-104	94	no standard	no standard
Magnesium (Mg)	10-80	31	no standard	no standard
Total Hardness (CaCO3)	168-589	362	100	500
Nitrate (as NO3)	15-184	42	45	70 in the absence of other sources
Color	No data	(5.0)	10 units	15 units
Iron (Fe)$^{+3}$ dissolved	No data	<0.01	0.3	1.0
Manganese (Mn)	No data	<0.01	0.1	0.2
Turbidity	0.0-7.7	0.50 (0.51)	1 unit	5 units
TSS	No data	(<4.0)	none	none
TDS	422-625	(400)	500	1,500
TOC	No data	(1.3)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml
Fecal Coliform	0->2400	can't average	0 MPN/100 ml	0 MPN/100 ml

Primary contamination in the Deek spring is from bacteria, possibly from animal feces or cesspits. As a result, the Deek spring is frequently shut down due to high coliform bacteria counts.

2.4.2 Quantity

Information on the quantity of water produced from the Deek and Teis springs have been compiled by the WQIC Project and are included in Appendix B. Data for the period April 1938 through September 1996 indicate maximum and minimum flows of 289 m^3/hr and 2 m^3/hr for the Deek spring and 511 m^3/hr and 23 m^3/hr for the Teis spring. The frequency of measurements taken from this data is shown in Figure 2-8 for the Deek spring and Figure 2-9 for the Teis spring.

From these figures, it is evident that the most frequent flow for the Deek spring is 85 m^3/hr, and the most frequent flow range is approximately 35 to 120 m^3/hr. Similarly, the most frequent flow is 75 m^3/hr from the Teis spring, while the most frequent flow range is 40 to 165 m^3/hr. The most frequent combined flow from the two springs is 160 m^3/hr.

Figure 2-8

Figure 2-9

Data provided by the WAJ for the last five years indicates that a combined annual average of 120 m^3/ hr has been produced by the Deek and Teis springs (50 m^3/hr from the Deek spring and 70 m^3/hr from the Teis spring). The proposed average design flow for the Deek/Teis WTP is 150 m^3/hr.

2.4.3 Site Civil and Mechanical Requirements

- Five pumps exist at the Deek pump station. Three pumps are on line at one time, and two are standbys. Two pumps are rated at Q=70 m^3/ hr, and H=100 meters; one is rated at Q=60 m^3/hr and H=450 meters; another is rated at Q=50 m^3/hr and H=240 meters; and the last is rated at 30 m^3/hr and H=400 meters.
- Because there is need for a raw water wet well to feed the WTP, it is recommended that the existing 200 m^3 reservoir be split into a raw water wet well and a finish water reservoir.
- A duty and standby pump, suction piping, valving, and pump pedestals should be installed to pump water from the raw water wet well to the package WTP.
- Discharge piping will need to be installed from the pump to the package WTP to provide sufficient operating pressure for the package treatment plant.
- Discharge piping from the package WTP must be connected to the finish water reservoir.
- The existing chlorination system will not need to be modified as it currently feeds the pump station's discharge force main.
- It is recommended that the WTP be located on a new reinforced concrete slab on grade between the reservoir and the pump station. The WTP and pumps should be covered by a steel sunscreen.
- The backwash pump is expected to be provided as part of the WTP. Approximately 80 m of backwash discharge piping will need to be installed to the nearby wadi.

2.4.4 Site Electrical Requirements

- There is no transformer on site. The pump station is powered by a 1000 KVA transformer located 150 m away from the site, which serves other portions of the community. The current electrical demand from the three pumps is 230 KW. Due to other electrical demands on this transformer, the WTP and pumps may require their own transformer.
- If a new transformer is required, a 500 KVA would be needed to power the pump station and new WTP equipment. The transformer could be installed in the electrical yard in the front of the pump station.

- A new main distribution box will need to be installed on site.
- WTP and pump controls will be combined in a single control panel adjacent to the new equipment.
- Outside lighting and electrical recepticles should be provided in the WTP area.
- Approximately 50 m of electrical wire will be needed to connect the package unit and circuit breaker.

2.4.5 Land Ownership and Space Constraints

- All existing facilities are within the property owned by WAJ.
- No additional space or new land acquisition is expected to be required other than the existing land.

2.4.6 Cultural Heritage Consideration of Construction Materials

- The pumphouse building is constructed of reinforced concrete walls. Installation of the package WTP will not affect the outside appearance of the existing pumphouse.

2.5 Kafrein Wells

The Kafrein wells are located southwest of Amman near the Dead Sea. The Kafrein site is 200 m below sea level and consists of 3 wells. Water from the wells is produced from the Kornub Aquifer. WAJ is developing a project to supply water from the Kafrein wells to three villages and several new hotels on the eastern shore of the Dead Sea.

WAJ design engineers intend to pump water from wells #4A, #11, and #12 to the villages of Suweimeh, Al Ramah, and Jofa and to the new hotels. These wells are flowing artesian wells, located approximately 0.5 km away from each other and several kilometers behind the Kafrein Dam operated by the Jordan Valley Authority (JVA). Each well is free flowing, in the range of 10 to 30 m^3/hr.

Currently the wells are cased to approximately 1 m above ground and are free flowing into small wadis. The wells are located in sandy, isolated, arid areas with little vegetation except in the immediate region where the discharge is flowing. The sites can be accessed best by 4-wheel-drive vehicles, since at least one large flowing wadi must be crossed to get to one well site.

A site plan of the Kafrein WTP is shown in Figure 2-10 and site pictures are shown on page 2-39.

Figure 2-10

Photo 9: Kafrein Well #11

Photo 10: Kafrein Well #12

2.5.1 Water Quality and Primary Sources of Contamination

Water quality information was provided on only one sample taken by WAJ during the site assessments for each Kafrein well. Note that each of these samples was taken when the wells were free flowing and not while being pumped at their fixed maximum well production rate. Although free-flowing water from the artesian wells appeared to be quite clear, WAJ field staff indicated that when pumped at their fixed well production rates, the water becomes turbid. According to WAJ staff, the turbidity values shown in Tables 5, 6, and 7 are representative of conditions when the wells are pumped at their design capacity. Sample results produced the WAJ Quality Control Department, and the laboratory results produced by CDM International Laboratories in Cambridge, Massachusetts are given in these tables. The CDM results, based on only one sample, are shown in parentheses, where they differ from the WAJ figure.

TABLE 5
Water Quality-Kafrein #11

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	80-199	91	no standard	no standard
Magnesium (Mg)	7.2-29	24	no standard	no standard
Total Hardness (CaCO3)	230-617	328	100	500
Nitrate (as NO3)	0-6.6	1.95	45	70 in the absence of other sources
Color	No data	(5.0)	10 units	15 units
Iron $(Fe)^{+3}$ dissolved	0.24-0.97	0.25	0.3	1.0
Manganese (Mn)	No data	0.08 (0.078)	0.1	0.2
Turbidity	43-185	93 NTU	1 unit	5 units
TSS	No data	(12)	none	none
TDS	536-589	(480)	500	1,500
Sulfur	0.29-0.63	0.63	0	0
TOC	No data	<0.01 (0.67)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total/Fecal Coliform	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml

TABLE 6
Water Quality-Kafrein #4

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)		100	no standard	no standard
Magnesium (Mg)		33	no standard	no standard
Total Hardness (CaCO3)		385	100	500
Nitrate (as NO3)		0.5	45	70 in the absence of other water sources
Color			10 units	15 units
Iron (Fe)$^{+3}$ dissolved		0.82	0.3	1.0
Manganese (Mn)			0.1	0.2
Turbidity		14.6 NTU	1 unit	5 units
TSS		794	none	none
TDS			500	1,500
Sulfur		0.56	0	0
TOC			2	same
Cadmium			0.005	same
Lead			0.05	same
Zinc			5	15
Mercury			0.001	same
Chromium			0.05	0.05
Total/Fecal Coliform	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml

TABLE 7
Water Quality-Kafrein #12

Component	Historical Concentration Range (mg/l)	Average Concentration (mg/l)	Permissible Jordan Standards for Drinking Water (mg/l)	Maximum Permissible Jordan Standards for Drinking Water (mg/l)
Calcium (Ca)	83-99	89	no standard	no standard
Magnesium (Mg)	39-47	44	no standard	no standard
Total Hardness (CaCO3)	368-439	404	100	500
Nitrate (as NO3)	0-1.18	0.35	45	70 in the absence of other sources
Color	No data	(5.0)	10 units	15 units
Iron (Fe)$^{+3}$ dissolved	0.02-3.45	0.57	0.3	1.0
Manganese (Mn)	No data	0.07 (0.77)	0.1	0.2
Turbidity	18.5-255	77.5 NTU	1 unit	5 units
TSS	No data	0.35 (10)	none	none
TDS	663-776	(600)	500	1,500
Sulfur	0.46-0.74	0.74	0	0
TOC	No data	(0.29)	2	same
Cadmium	No data	<0.01	0.005	same
Lead	No data	<0.01	0.05	same
Zinc	No data	<0.01	5	15
Mercury	No data	<0.01	0.001	same
Chromium	No data	<0.01	0.05	0.05
Total/Fecal Coliform	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml

2.5.2 Quantity

According to WAJ and field observations made by its staff, approximately 10 to 30 m^3/hr flows from each of the three Kafrein wells in this project. Their existing flow rates and WAJ projected well yields are shown in Table 8 below:

TABLE 8
Flow Rates - Kafrein Wells

Well	Existing Flow Rate	WAJ Projected Well Yield to be Used for Design
Kafrein Well # 12	10 m^3/hr	80 m^3/hr
Kafrein Well # 11	10 m^3/hr	50 m^3/hr
Kafrein Well # 4A	10 m^3/hr - 30 m^3/hr	125 m^3/hr
Total		255 m^3/hr

2.5.3 Site Civil and Mechanical Requirements

– Three wells have been drilled and casings installed.

– Pumps and well discharging piping, including metering vaults, will be required at each well site.

– A small building with the pump control panel and motor control panel will be required at each well site.

– Fencing around the well compound will be required at each site.

– Approximately 7 km of ductile iron delivery pipe will be required to convey water from the three wells to a central WTP.

– Depending on the treatment technology, a raw water wet well may be required upstream of the WTP.

– A 1000 m^3 storage reservoir will be required downstream of the WTP to convey the finish water to the distribution system by gravity.

– A small maintenance building is recommended for this site to house the well and WTP controls and to help maintain the system.

– A graded dirt road will be required to access the proposed WTP and reservoir site.

2.5.4 Site Electrical Requirements

- Electrical power will have to be conveyed approximately 7 km to each of the three well locations.

- A 75 KVA transformer will have to be pole-mounted at each of the well sites.

- Exterior lighting will have to be supplied to each well site.

- Multicord instrumentation cable will have to be conveyed to each well site to control the pumps.

- An individual pump control system at each well site will have to be installed and connected to a master pump control system at the WTP.

- A main transformer will have to be installed at the WTP.

- Area lighting will need to be provided at the WTP area.

- All electrical works for the WTP and maintenance building will be required.

2.5.5 Land Ownership and Space Constraints

- It appears that the land at the proposed WTP location is owned by JVA. Prior to the start of detailed design activities, JVA's ownership of the proposed site must be clearly established.

- It is unclear who owns the land at the three well locations. Prior to the start of routing of conveyance piping, land ownership of the proposed sites must be resolved.

2.5.6 Cultural Heritage Consideration of Construction Materials

- The proposed location of the WTP and reservoir is in a rural desert environment adjacent to a Jordan Valley Authority Office compound. The pumphouse building and reservoir should be constructed out of reinforced concrete.

Chapter 3
Treatment Technologies

In designing any water treatment system, the choice of technologies is influenced by the primary contaminants which must be treated, the operation and maintenance capabilities of local maintenance personnel, and the level of service which the country can sustain. An additional factor in the choice of technology in this activity is the emergency need to provide adequate water treatment for four springs in five or six months. This chapter includes a description of appropriate treatment technologies and options for the Wadi Sir, Qairawan, Qantara, Deek/Teis, and Kafrein sites along with a site plan for each setting with the proposed water treatment package and necessary site modifications. A discussion of the level of service which can be sustained is found in Chapter 6.

3.1 Appropriate Treatment Technologies and Recommendations

Typically, the springs produce less water at the beginning of the dry season (May), and fecal coliform counts increase. WAJ water quality experts indicate that this occurs because sources of contamination, such as exfiltration of cesspits and contaminated surface run-off, are no longer diluted by precipitation.

Historical data from WAJ confirm that coliform counts in summer are increasing. This situation is complicated by the fact that WAJ is under increasing pressure to provide adequate water supplies during the summer season, and yet MOH policies frequently require many water sources to be shut down due to increased public health risk.

WAJ staff indicate that it is MOH policy to shut down any water source when its fecal coliform count (before chlorination) is greater than 25 MPN per 100 ml, unless additional treatment facilities exist. Because less coliform was present in past years, MOH and WAJ believe that rising coliform levels indicate that spring water is increasingly being influenced by surface water sources and pathogens that are often present in surface water, including bacteria, viruses, cryptosporidia, and giardia.

3.1.1 Wadi Sir, Qairawan, Qantara, Deek/Teis

According to water quality tests performed by the WAJ, the primary contaminants detected at the Wadi Sir, Qairawan, Qantara, and Deek/Teis systems are coliform bacteria. Presently, the WAJ does not have the capability to measure for giardia and crytosporidium.WAJ water quality staff believe that fecal coliform counts in the range of 25 to greater than 2,400 MPN per 100 ml and nitrate concentrations in the range of 45 mg/l (as NO_3) indicate that these spring water sources may be influenced from domestic sewage.

These concerns seem justified. Because identification of specific types of pathogenic bacteria is quite difficult and laborious, laboratories usually attempt to determine the presence or absence of coliform organisms. Because coliform organisms originate primarily in the intestinal tract of warm-blooded animals, their presence suggests that conditions are appropriate to support pathogenic organisms and that fecal contamination is possible.

Moreover, MOH and WAJ staff believe that the presence of coliform indicates that spring water is being influenced by surface water sources. Pathogens often present in surface water include bacteria, viruses, cryptosporidia, and giardia. For this reason, WAJ staff have specifically asked for package WTPs which include a high degree of filtration.

Cryptosporidia and giardia are parasitic micro-organisms. Giardia lambia is a cyst which cannot be inactivated by disinfection alone; its removal requires granular filtration, in-depth filtration, or filtration by diatomaceous earth. Similarly, cryptosproridium is a spore which cannot be inactivated by disinfection alone. Cryptosporidia enter the water supply from animal feces and travel from host to host as an oocyst, 4-6 microns in size. A single oocyst can cause severe illness, prolonged diarrhea and vomiting, and even death in the elderly or sick.

WAJ staff are also concerned about spore-forming bacteria which become inert when their environment becomes hostile to them, but can grow again when the environment becomes suitable.

Turbidity in the springs is generally low (with average ranges of less than one NTU) for the Wadi Sir, Qairawan, Qantara, and Deek/Teis spring water sources. However, when heavy rains occur, some sources, especially the Wadi Sir spring, become turbid. In the past, WAJ staff have dealt with the higher turbidity levels at the Wadi Sir spring by bypassing the pumping facility when this occurs. WAJ engineers estimate that this occurs approximately 10 days per year.

Surface water often contains suspended solids and soluble organic matter. Although turbidity in groundwater is rare, shallow groundwater can be high in soluble organic matter. Eliminating this matter helps remove contaminants that cling to suspended solids.

Natural nitrate concentration in groundwater ranges from 4.5 to 45 mg/l as NO_3. Sources include plants which fix atmospheric nitrogen and transfer it to soil. Other sources include decomposing plant debris, animal wastes, sewage discharges on land, industrial wastes, and nitrate fertilizers. A high nitrate content can be considered an indicator that an aquifer should be tested for pathogenic bacteria which may accompany contamination from these sources. Water containing 90 mg/l of nitrate is considered harmful to infants. The conversion of nitrates to nitrites in the intestines of infants can result in an overabundance of methemoglobin molecules which reduces oxygen uptake. The Jordanian maximum permissible limit for nitrates is 70 mg/l. According to water quality tests, most water quality analyses fall below this limit. However, because nitrate in groundwater results most often from sewage waste, it is a good indicator that the springs may be impacted by pathogenic bacteria.

Total organic carbon values for all sites are below permissible water quality limits; thus, organic chemicals such as pesticides and industrial wastes do not appear to be sources of contamination which must be addressed. Similarly, heavy metals, including lead, mercury, cadmium, chromium, nickel, copper, and zinc, all appear to be within normal limits.

The range of typical filtration technologies available in package WTPs, and some of their capabilities, is shown below:

<u>Conventional Filtration</u>
- Can remove particles in the range of 3 to 100+ microns.

<u>Multimedia Filters</u>
- Can reduce suspended solids by 90 to 98%; however, does not remove dissolved organic compounds.
- Some types can remove giardia and cryptospróridium.
- Remove particles in the range of 3 to 100+ microns, but superior to conventional filtration in filtering capacity.

<u>Microfiltration</u>
- Can remove particles in the range of 0.4 to 3 microns
- Can remove a large amount of bacteria.
- Can remove giardia and cryptosporidium.

<u>Ultrafiltration</u>
- Can remove particles in the range of 0.0025 to 1 micron.
- Can remove giardia and cryptosporidium.
- Can remove all bacteria.
- Can remove viruses.

<u>Nanofiltration and Reverse Osmosis</u>
- Removes particles in the range of less than 0.0006 to 0.06 microns.
- Can remove viruses.
- Because R.O. and nanofiltration remove such small particles, some form of pretreatment is generally necessary.
- Membranes are subject to fouling or deterioration if not properly operated.
- Removes ionic species, TOC, color, and disinfection byproduct precursors.

Considerations

Some micro-, ultra-, and nanofiltration units cannot tolerate continuous exposure of the membrane to chlorine residuals. Thus, the membrane material will have to be evaluated in relation to the backwash arrangement at the existing sites. That is, if chlorinated water is to be used for backwashing, the type of membrane material proposed could become a significant selection parameter in this application.

Smallest bacteria are in the range of 0.2 microns; coliform bacteria are approximately 0.45 microns. Microfiltration would remove most pathogenic bacteria. In addition, the filtration of suspended solids which bacteria and viruses cling to would provide an added degree of protection. Typical microfiltration units being suggested by vendors can remove 98% of particles down to 2 microns, and 90% of materials down to 1 micron.

The types of technology which may be appropriate for installation at the springs include multimedia filters with chemical oxidation (typically prechlorination), microfiltration, and ultrafiltration. Although acceptable package treatment technologies can be narrowed down to these three applications, each specific technology varies by vendor and has tradeoffs in terms of energy requirements, operating pressures, operational costs, allowable influent water temperatures, recurring maintenance costs, and ease of operation. These technologies will have to be evaluated on a package-by-package basis. Criteria for the tender package are shown in Section 3.2.

3.1.2 Kafrein Wells

Primary contaminants in the Kafrein wells are high turbidity and high hydrogen sulfide. When pumped at their fixed well yield, the Kafrein wells become turbid. This turbidity may improve over time, as the wells are consistently pumped at these higher rates and the gravel packs stabilize around each slotted well casing (screen) intake.

Groundwater at the Kafrein wells contains hydrogen sulfide, which produces a "rotten egg" smell when released to the atmosphere. Air stripping or chemical oxidation would remove the odor. Turbidity can be reduced by clarification, sedimentation, filtration, or a combination of them.

Some technologies suggested by vendors include a treatment unit that can accomplish both chemical oxidation and filtration in one package unit. Local WAJ treatment plant operators indicate that they have some experience with air-stripping treatment processes.

Vendor submittals will need to be reviewed and assessed based on simplicity, ease of operation, recurring maintenance costs, and the like. A list of vendor criteria is given below.

3.2 Vendor Criteria

As part of the design/build process, a vendor will be selected to provide the package WTPs. To meet the project's aggressive schedule, several vendors are in the process of developing their recommended technologies based on water quality and quantity information submitted to them. A limited competitive tendering process will be conducted requiring the vendors to submit financial and technical proposals.

Their proposals will be evaluated by the criteria listed below:

1. Financial
    a) Capital cost of equipment
    b) Recurring maintenance costs
    c) Operation costs
    d) Shipment costs
    e) Installation costs
    f) Availability, length, and cost of warranty

2. Technical

a) Compliance with technical requirements
b) Ability of technology to react quickly to seasonal contamination, including a sudden increase in turbidity and/or flow rates
c) Compatibility with local physical environment, including space constraints
d) Ease of operation and maintenance
e) Availability of spare parts and consumables
f) Ability to be compatible with existing chlorination facilities
g) Ability to minimize the number of technologies used
h) Ability to provide overseas training on operation and maintenance of equipment.

3. Responsiveness
   a) Ability to fabricate package unit in short timeframe
   b) Ability to prepare the unit quickly for shipment
   c) Ability to rapidly install equipment
   d) Ability to meet May 1998 installation schedule

4. Experience
   a) Successful history of installations using recommended technologies
   b) Ability to demonstrate technology application in International locations
   c) History of experience in the Middle East
   d) History of overseas installation, operation, maintenance, and training experience.

3.3 U.S. Source and Origin Requirements

To comply with USAID regulations, the choice of appropriate technologies must meet U.S. source and origin requirements. However, because a number of qualified U.S. package treatment plant manufacturers exist, this requirement should have little effect on the technology selected for these applications.

3.4 Site Plans Showing Proposed Facilities

Schematics and site plans have been developed for each of the four spring locations. Site plans for the proposed WTP and reservoir locations have also been developed for the Kafrein wells. These proposed designs are based on the installation of package treatment units at all the sites. Many of the civil, mechanic, and electrical requirements outlined for each site in Chapter 2 are incorporated into the proposed designs. After the selection of the package WTP vendor, these designs will be more fully developed during the design/build process. These schematics and proposed site plans are shown in Figures 3-1 to 3-9.

Figure 3-1
Wadi Sir Spring Proposed Schematic

Figure 3-2
Wadi Sir Pump Station Proposed Site Plan

Figure 3-3
Qairawan Spring Proposed Schematic

Figure 3-4
Qairawan Pumpt Station Proposed Site Plan

Figure 3-5
Qantara Spring Proposed Schematic

Figure 3-6
Qantara Pump Station Proposed Site Plan

Figure 3-7
Deek Spring Proposed Schematic

Figure 3-8
Deek/Teis Pump Station Proposed Site Plan

DEEK/TEIS PUMP STATION - PROPOSED SITE PLAN

Figure 3-9
Kafrein WTP Proposed Site Plan

Chapter 4
Environmental Affects Associated with Proposed Treatment

As described in Chapter 1, because of high bacterial levels during the summer season, the Ministry of Health has required the Wadi Sir, Qairawan, Deek/Teis, and Qantara pumping stations to be shut down. As a result, many residents in the distribution zones of each spring receive water only once every 10 to 14 days from other zones. The loss of these potable water sources has imposed extreme hardship on local residents and increased public health risks to approximately 125,000 people. To address the emergency need for drinking water in these locations by May 1998, USAID is supporting the rehabilitation of these priority springs through the installation of package water treatment plants which provide filtration. This chapter discusses the environmental affects associated with installation of the treatment plants and the pumping station modifications necessary to install the units.

4.1 Wadi Sir

Spring Production Capabilities

Summarizing from Section 2.1.2, the most frequent flow according to the distribution of measurements over the last 59 years is 250 m^3/ hr. According to WAJ, flow averages over the last five years have been 350 m^3/hr in the summer, 500 m^3/hr in the winter, with an annual average of 400 m^3/hr.

Water Demand and Capacity of Original Conveyance System

According to a review of the existing pump arrangement at the Wadi Sir pump station and discussions with WAJ engineers, an average of 350 to 400 m^3/hr is delivered on a regular basis to 70,000 people. Water leaving the Wadi Sir pumping station is chlorinated and pumped through three main lines to (1) Al Hussein Medical City, (2) a reservoir which serves residents of Wadi Sir, and (3) several small villages.

WAJ engineers estimated that approximately 65% of the flow is delivered to the Wadi Sir reservoir to serve Wadi Sir residents. About 20% of the flow is delivered to the villages of Eraq Al-Amer, Um-Asus, Bader, and other smaller dispersed villages. (Eraq Al-Amer is projected to grow in the future.) The remaining 15% is pumped to the Al Hussein Medical City.

Consumption Pattern

Because of high fecal coliform levels, MOH has frequently required this source to be shut down. Indeed, at the time of this study (November 1997), the pumping station was shut down due to high fecal coliform levels.

When the Wadi Sir spring is shut down, a valve is opened at the Wadi Sir pump station so that water can be drawn from other water sources in the supply network, including the Al Hedan wells and Zay systems. When this happens, the water supply available to residents in South Amman and Madaba, who depend on those sources, is reduced. When the Wadi Sir spring is shut down and the system supplemented with water from the Al Hedan wells and Zay systems, beneficiaries of the Wadi Sir system also receive much less water than usual or needed, and even that, only periodically. For example, the hospital receives 30 to 40 m^3/hr of flow only one day per week; the villages receive 100 m^3/hr of flow only two days per week; and the Wadi Sir reservoir is provided with 250 m^3/hr of flow only two days per week.

To make up for this reduced supply of water, vendors deliver water to residents in tanker trucks. Unfortunately, according to local reports many of these vendors fill their trucks with the contaminated spring water and then sell it to residents. (The authors of this report observed this during the site visits as well.)

Potential Sources of Contamination and Proposed Technology

The primary sources of contamination are bacteria and other pathogens. WAJ engineers speculate that drainage from cesspit tanks and surface water drainage may contribute to the bacterial contamination. As discussed in Chapter 3, the proposed technology to address this problem at Wadi Sir is filtration.

Impacts from Proposed Technology

– Health Benefits and Quality of Life

The loss of this potable water source has increased public health risks to approximately 70,000 people. Depending on water consumption, improved treatment at the Wadi Sir spring would mean as many as 70,000 residents per day would have access to a reliable, safe water source. The increased availability of water will have a positive effect on public health, including the provision of adequate water for sanitation.

The project would greatly improve the quantity and quality of water available to the Al Hussein Medical City, the villages of Eraq Al-Amer, Um-Asus, Bader, and other smaller dispersed villages, and portions of greater Amman. In addition, this project would reduce the need to divert water from the Al Hadan and Zay systems, thereby increasing the amount of water available to residents of South Amman and Madaba.

– Wastewater Production

Wastewater produced from delivery of water to homes is collected and transferred to the Wadi Sir wastewater treatment plant or is disposed of in cesspits. WAJ engineers indicate that most wastewater generated by the Al Hussein Medical City and urban households served by the Wadi Sir spring is collected and conveyed to the Wadi Sir wastewater treatment plant, a new facility with secondary treatment that has been in operation for only one year. Although all households in the Wadi Sir area are served with sewer service connections up to their property boundary, many are not yet connected to the sewage system. They rely on cesspits.

Similarly, wastewater from the villages is disposed of in on-site cesspits or is conveyed to the new wastewater treatment plant in Wadi Sir.

Installation of a package water treatment plant at the Wadi Sir spring would mean that overall water deliveries to beneficiaries would increase during the summer months, since up to now, the spring has frequently been shut down due to high bacterial counts. The volume of water and wastewater would be the same as those portions of the year when the water source is not contaminated.

– Backwash Water Disposal

Filters will have to be regularly backwashed when the differential pressure across the filter becomes too great. That is, flow will have to be reversed periodically through the filter to remove the particulate matter from the filter. Depending on the WTP technology selected, the length of the backwash cycle can be relatively short, often as short as three minutes. However, the number of backwash cycles will depend on the amount of suspended materials, turbidity, and particulates in the influent water. In the case of Wadi Sir, turbidity is expected to occur less than 10 days per year, i.e., in the winter when run-off is higher than normal.

A sewage collection system is available near the location where the Wadi Sir package treatment unit will be installed. Thus, chlorinated backwash water from the treatment unit can be released into the sewage system. (The collector is located 20 to 30 m from the Wadi Sir pumping station.) The backwash water will then be conveyed to the Wadi Sir wastewater treatment plant.

– Archeological Considerations

There are no known archeological ruins at this site. Nearly all construction is envisioned to take place within the existing pump station facility. However, an archeologist will be retained to conduct an archeological survey at the site and will propose adequate measures for mitigating negative impacts to ensure that the project meets provisions of Antiquities Law No. 21, 1988, especially Articles 6, 13, 14, 15, 16 and 29.

4.2 Qairawan

Spring Production Capabilities

As mentioned in Section 2.2.2., the most frequent flow according to the distribution of measurements over the last 59 years is 125 m^3/ hr (with a maximum flow of 359 m^3/ hr and a minimum flow of 60 m^3/ hr). According to WAJ, flow averages over the last five years, have been 120 m^3/hr in the summer, 170 m^3/hr in the winter, with an annual average of 150 m^3/hr.

Water Demand and Capacity of Original Conveyance System

According to a review of the existing pump arrangement at the Qairawan pump station and discussions with WAJ engineers, an average of 150 m^3/hr is delivered on a regular basis to 30,000 people. Water leaving the Qairawan pumping station is pumped through three main lines to (1) the network of Al Saru area near

Jerash, (2) an old reservoir which serves part of Jerash, and (3) a new reservoir which also serves water distribution networks in Jerash.

Consumption Pattern

Although the Qairawan pumping station is currently on line, when fecal coliform counts are greater than 25 MPN per 100 ml, the pumps are shut down to comply with MOH regulations. (This was the case in November 1997, less than a month before the authors' site visit.)

Potential Sources of Contamination and Proposed Technology

The primary sources of contamination are bacteria and other pathogens. WAJ engineers speculate that drainage from cesspits and surface water drainage may contribute to the bacterial contamination. As discussed in Chapter 3, the proposed technology suggested for Qairawan is filtration.

Impacts from Proposed Technology

– Health Benefits and Quality of Life

The loss of these potable water sources has increased public health risks to approximately 30,000 water recipients. Improved treatment at the Qairawan Spring would mean as many as 30,000 residents of Jerash would have access to a reliable, safe water source. The increased availability of water will have a positive effect on public health, including the provision of adequate water for sanitation.

– Wastewater Production

WAJ engineers estimate that 10 to 25% of homes served by the Qairawan spring dispose of wastewater in some type of on-site cesspit. WAJ engineers estimate that 75 to 90% of wastewater generated by these residents is collected and transferred to the Jerash wastewater treatment facility.

Installation of a package water treatment plant at the Qairawan spring would mean that overall water deliveries to beneficiaries would increase during the summer months, since in the past the spring has frequently been shut down due to high bacterial counts. However, the volume of water and wastewater in these summer months would still be consistent with delivery capacities when the water source is not contaminated.

– Backwash Water Disposal

Filters will have to be backwashed regularly when the differential pressure across the filter becomes too great. That is, flow will have to be reversed periodically through the filter to remove the particulate matter from the filter. Depending on the technology selected, the length of the backwash cycles can be relatively short, often as little as three minutes. The number of backwash cycles will depend on the amount of suspended materials, turbidity, and particulates in the influent. In the case of the Qairawan, little turbidity is expected, except perhaps in spring when runoff is higher than normal.

A sewage collection system is available near the location where the Qairawan package treatment unit will be installed. As a result, chlorinated backwash water from the water treatment system will be need to released into this wastewater system. The collector is located only 10-15 m from the Qairawan pumping station. The backwash will then be conveyed to the Jerash wastewater treatment plant.

– Archeological Considerations

A visual archaeological survey has been conducted by traversing across the area and surveying at intervals designed to locate buried resources. Historical archaeological ruins have been identified in the eastern section of the Qairawan pump station compound. The location of these remains have been noted and mapped (see Figure 2-3). These ruins date from the Roman period. A recently constructed stone and reinforced concrete structure covers these ruins. They are located uphill and upstream from where the majority of the spring water is captured today.

The package treatment plant will be installed near the pump room (see Figure 3-4). Few major structural plant modifications are envisioned for installation of the package treatment unit. Some leveling and/or the removal of an interior wall may be necessary for installation of the proposed package unit; these areas, however, are at least 15-20 m from the historical area. In addition, roofing and provisions for heating may need to be installed. If leveling or the removal of the wall, or installation of roofing and heating units is necessary, precautions will be taken to ensure that there is no disturbance to the archeological ruins.

A reservoir to store treated water is planned for the southern section of the pumphouse compound. This area is located at least 34-50 m from the historical portion of the site. Up to one meter of earth may need to be excavated to build the foundation for this reservoir. This work will be performed cautiously to ensure that no existing antiquities are disturbed and that any unearthed ruins are immediately identified. An archeologist will be retained to conduct an archeological survey at the site and will propose adequate measures for mitigating negative impacts to ensure that the project meets provisions of Antiquities Law No. 21, 1988, especially Articles 6, 13, 14, 15, 16 and 29.

4.3 Qantara

Spring Production Capabilities

Summarizing from Section 2.3.2., the most frequent flow according to the distribution of measurements over the last 59 years is 110 m^3/ hr (with a maximum flow of 335 m^3/ hr and a minimum flow of 10 m^3/ hr). According to WAJ, flow averages over the last five years, have been 100 m^3/hr in the summer, 150 m^3/hr in the winter, with an annual average of 120 m^3/hr.

Water Demand and Capacity of Original Conveyance System

According to a review of the existing pump arrangement at the Qantara pump station and discussions with WAJ engineers, an average of 120 m^3/hr is delivered on a regular basis to 25,000-30,000 people. Water leaving the Qantara pumping station is pumped through two main lines to the distribution networks in Ajlun and Kufrangeh.

Consumption Pattern

When fecal coliform counts are greater than 25 MPN per 100 ml, this source is shut down to comply with MOH regulations. (At the time of the authors' visit, the source was shut down.) When this occurs, the supply to residents in Ajlun and Kufrangeh is significantly reduced, and water is provided on rationed basis from other zones in the distribution network.

Potential Sources of Contamination and Proposed Technology

Contamination is due mainly to bacteria and other pathogens. Approximately 100 to 200 homes dispose of their sewage in a wadi located 2 km upstream from the spring. WAJ engineers speculate that drainage from the wadi may contribute to the bacterial contamination in the spring. WAJ engineers indicate that conceptual plans have been developed to install approximately 600 m of sewage collector pipe on one side of the wadi and approximately 1000 m on the other side. These plans, however, may take 2 to 3 years to be fully implemented. WAJ engineers are anxious to provide a solution for improved water quality at the Al Qantara spring by May 1998. The proposed technology being suggested is filtration.

Impacts from Proposed Technology

– Health Benefits and Quality of Life

The loss of this potable water source has increased public health risks to approximately 25,000-30,000 water recipients and imposed hardship on them. Improved treatment at the Qantara spring would mean up to 30,000 residents of Ajlun and Kufrangeh would have access to a reliable, safe, water source. The increased availability of water will have a positive effect on public health, including provision of adequate water for sanitation.

– Wastewater Production

Of the 25,000 to 30,000 residents in Kufrangeh and Ajlun, WAJ engineers estimate that 10 to 25% have some type of existing on-site cesspits for wastewater disposal, while 75 to 90% are connected to a sewage collection system. That system, serving both communities, terminates at the wastewater treatment plant in Kufrangeh. The plant has biological treatment.

Installation of a package water treatment plant at the Qantara spring would mean that overall water deliveries to beneficiaries would increase during the summer months, since in the past the spring has frequently been shut down due to high bacterial counts. However, the volume of water and wastewater would still be consistent with delivered capacities when the water source is not contaminated.

– Backwash Water Disposal

Filters will have to be regularly backwashed when the differential pressure across the filter becomes too great. That is, flow will have to be periodically reversed through the filter to remove the particulate matter from the filter. Depending on the technology selected, the length of the backwash cycles can be relatively short, often as little as 3 minutes. The number of backwash cycles needed will depend on the amount of suspended materials, turbidity, and particulates in the influent water. In the case of Qantara, little turbidity is expected, except perhaps in spring when runoff is higher than normal.

No sewage collection system is available near the location where the Qantara package treatment unit will be installed. Thus, chlorinated backwash water from the system will be need to released into a nearby wadi. Plans call for approximately 1000 m of sewer collector pipe to be installed on the far side of the wadi. Although these plans are only conceptual, if implemented, the backwash water from the Qantara treatment unit could be connected to the sewage collection system and conveyed to the Kufrangeh wastewater treatment plant.

– Archeological Considerations

There are no known archeological ruins at this site. Nearly all construction is envisioned to take place within the existing pump station facility and reservoir area. An archeologist will be retained to conduct an archeological survey at the site and will propose adequate measures for mitigating negative impacts to ensure that the project meets provisions of Antiquities Law No. 21, 1988, especially Articles 6, 13, 14, 15, 16 and 29.

4.4 Deek/Teis

Spring Production Capabilities

Summarizing from Section 2.4.2., the most frequent flow according to the distribution of measurements over the last 59 years is 85 m^3/ hr for the Deek spring, 75 m^3/ hr for the Teis spring, and 160 m^3/ hr for the combined flow. According to WAJ, combined flow averages over the last five years, have been 120 m^3/hr, with an average of 50 m^3/hr originating from the Deek spring and 70 m^3/hr originating from the Teis spring.

Water Demand and Capacity of Original Conveyance System

According to a review of the existing pump arrangement at the Deek/Teis pump station and discussions with WAJ engineers, an average of 120 m^3/hr is delivered on a regular basis to 30,000 people. Water leaving the Deek/Teis pumping station is pumped through three main lines to the water distribution networks in Gaza refugee camp, the Debein area, and the village of Kitah.

Consumption Pattern

When fecal coliform counts are greater than 25 MPN per 100 ml, this source is shut down to comply with MOH regulations. (The Deek spring was shut down at the time of the authors' visit.) Water was being produced from the Deek/Teis pumping station at a reduced rate (approximately 70 m^3/hr). As a result, the Gaza refugee camp, the Debein area, and the village of Kitah were being supplied with water only on an intermittent basis.

Potential Sources of Contamination and Proposed Technology

Contamination is primarily caused by bacteria and other pathogens. WAJ engineers speculate that drainage from septic tanks and surface water drainage may contribute to the bacterial contamination. In the case of the Deek spring, some contamination may be the result of rodent activity near the spring source. As discussed in Chapter 3, the proposed technology for Deek/Teis is filtration.

Impacts from Proposed Technology

– Health Benefits and Quality of Life

The loss of these potable water sources has increased public health risks to approximately 30,000 water recipients and imposed hardship on local residents. Improved treatment at the Deek/Teis pump station would mean as many as 30,000 residents of the Gaza refugee camp, Debein area, and village of Kitah would have access to a reliable, safe, water source. The increased availability of water will have a positive effect on public health, including provision of adequate water for sanitation.

– Wastewater Production

WAJ engineers estimate that nearly all the residents in the service area have some type of on-site cesspits for wastewater disposal, and that none of these areas are connected to formal sewage collection systems. Because MOH prohibits, regulates, and closely monitors dumping of waste into wadis in this area, WAJ engineers believe that nearly all residents in the Deek/Teis area are using some type of acceptable on-site wastewater disposal system. Staff of WAJ are currently discussing potential wastewater treatment projects for the Deek area with foreign donors. If a wastewater collection and treatment system is implemented in the future, it will provide a high degree of treatment for wastewater.

Installation of a package water treatment plant at the Deek/Teis pump station would mean that overall water deliveries to beneficiaries would increase during the summer months, since in the past the spring has frequently been shut down due to high bacterial counts in the summer. The volume of water and wastewater would still be consistent with delivered capacities when the water source is not contaminated.

– Backwash Water Disposal

Filters will have to be regularly backwashed when the differential pressure across the filter becomes too great. That is, flow will have to be periodically reversed through the filter to remove the particulate matter from the filter. The length of the backwash cycles is relatively short, often as short as three minutes. The number of backwash cycles needed will depend on the amount of suspended materials, turbidity, and particulates in the influent water. In the case of the Deek/Teis springs, little turbidity is expected, except perhaps in spring when runoff is higher than normal.

There is no sewage collection system near the location where the Deek/Teis package treatment unit will be installed. However, a wadi is located directly adjacent to the pumping station. As noted earlier, the Deek and Teis springs are located on each side of a large wadi. Currently, water from several other smaller springs located on both sides of the wadi drain into the wadi bottom. While some of this flow is removed for irrigation, WAJ engineers estimate a summer flow of 60 m^3/hr, and even more in winter. Since there is no sewage collection system available near the location where the water treatment facility will be installed, chlorinated backwash water will have to be released into this wadi. Because water is flowing in the wadi, backwash water from the Deek/Teis treatment facility will be diluted when released into the wadi.

– Archeological Considerations

There are no known archeological ruins at this site. Nearly all construction is envisioned to take place within the existing pump station facility and reservoir area. An archeologist will be retained to conduct an archeological survey at the site and will propose adequate measures for mitigating negative impacts to ensure that the project meets provisions of Antiquities Law No. 21, 1988, especially Articles 6, 13, 14, 15, 16 and 29.

4.5 Kafrein

Well Production Capabilities

The Kafrein site is located 200 m below sea level and consists of 3 wells. WAJ design engineers intend to use 255 m^3/hr from Kafrein wells #12, #11, and #4A to supply water to seven planned hotels and existing populations in Suweimeh, Al-Ramah, and Jofa. The fixed-well yield from wells #12, #11, and #4A are 80 m^3/hr, 50 m^3/hr, and 125 m^3/hr, respectively.

Water Demand and Capacity of Original Conveyance System

WAJ engineers indicate that the water demand for the region is 9600 m^3/day (or 400 m^3/hr); thus the 255 m^3/hr from the Kafrein wells meets approximately 64% of the total service demand. Another wellfield, Karama, is planned to provide additional supply to the site; however, according to WAJ engineers, iron will need to be removed at the Karama sites. Roughly 50% of the 9600 m^3/day demand is projected to be delivered to the hotels.

Consumption Pattern

Because there is no existing distribution system, no consumption pattern has been established. Because these wells are not contaminated with coliform, temporary service shut-offs to protect public health are not anticipated.

Potential Sources of Contamination and Proposed Technology

The primary source of contamination at Kafrein is sulfur and high turbidity. As discussed in Chapter 3, the proposed technology being suggested includes aeration towers, filtration, and clarification.

Impacts from Proposed Technology

– Health Benefits and Quality of Life

Depending on consumption levels, water from the Kafrein wells could serve as many as 50,000 residents per day (based on an average residential consumption of 120 l/c/d). The increased availability of water will have a positive effect on public health, including provision of adequate water for sanitation.

The project, involving construction of pipelines and treatment, will greatly improve the availability of water to at least three communities. The project is also likely to be associated with increases in tourist development, a rapidly expanding economic interest of the area.

– Wastewater Production

With the increase of water supply to the communities of Suweimeh, Al-Ramah, and Jofa and the new hotels, there will be an increase in wastewater produced. Construction on two hotels has already begun. WAJ engineers estimate that in all, seven hotels may be constructed within the next two to three years. At this point, the hotels have not yet submitted any treatment plans to the WAJ for wastewater they generate. However, under the direction of the Jordan Valley Authority, a design has been prepared for a central wastewater treatment plant which would treat wastewater from the hotels. To date, no tender package has been advertised for construction of this plant.

Wastewater generated by residents of Suweimeh, Al-Ramah, and Jofa is disposed of in on-site cesspits. The increased availability of water from the Kafrein wells will increase the volume of wastewater going into these pits.

– Backwash Water Disposal

Filters will have to be regularly backwashed when the differential pressure across them becomes too great. That is, flow will have to be periodically reversed through the filter to remove the particulate matter from the filter. The number of backwash cycles will depend on the amount of suspended materials and particulates in the influent water. In the case of the Kafrein wells, high turbidity is expected, especially initially, when the wells are pumped at their fixed well-yield capacity. Thus, the number of backwash cycles required is expected to be higher than those for the four priority springs.

No sewage collection system is available near the location where the Kafrein package treatment unit will be installed. As a result, chlorinated backwash water from the system will be released into a nearby wadi. A raw water pipe from the well-field conveyance system can be connected to the backwash disposal pipe to provide dilution of backwash water if needed.

– Aquifer Recharge

WAJ design engineers plan to pump 255 m^3/hr from Kafrein wells #12, #11, and #4A to supply water to approximately seven hotels and some areas in the Suweimeh region. Currently, these three wells are flowing artesian wells, i.e., these wells have been drilled through overlying impervious layers into a confined aquifer. The confined pressure causes each of them to free flow in the range of 10 to 30 m^3/hr

WAJ staff have pump tested each of the three wells. The results are shown in Table 9.

TABLE 9
Kafrein Pump Test Results

Well	**Static Water Level**	**Drawdown during pumping test**	**Well Yield - Fixed Well Production Rate at Level of Drawdown**	**WAJ Recommended Pumping Rate for Design**
Kafrein Well # 12	Flowing, 10-m^3/hr	34.2 m	80.5 m^3/hr	80 m^3/hr
Kafrein Well # 11	Flowing, 10-m^3/hr	223.55m	77.8 m^3/hr	50 m^3/hr at a drawdown of 240 meters
Kafrein Well # 4A	Flowing	31.5 m	125 m^3/hr	125 m^3/hr with the depth of pump at 100 meters
Total				255 m^3/hr

Geologists from the WAJ Well Committee and the Director of the WAJ Water Study Department indicate that they do not expect to overdraft the aquifer since the wells are flowing. They believe that the water from the wells is produced from the Kornub aquifer, a renewable aquifer. The Kornub aquifer is approximately 300 to 350 m in thickness and is composed of sandstone. The top of the Kornub aquifer is at approximately 420 m of depth (and therefore extends to 720-770 m of depth.) Underlying this aquifer is the Zarqa aquifer which is saline.

Although no information is available on natural recharge of the Kornub aquifer, geologists from the WAJ Well Committee and the Director of the WAJ Water Study Department indicate that they plan to develop a monitoring network for the Kafrein area using at least two new monitoring wells and the other Kafrein wells not being used for this water supply project. The Director of the WAJ Water Study Department hopes that the monitoring system will be completed before the Kafrein transmission and distribution piping system is constructed. Currently, the WAJ also has no information on the potential for artificially recharging the aquifer.

The WAJ staff have tried to minimize any saltwater intrusion in the aquifer by drilling wells to levels above the Zarqa aquifer which becomes more saline with depth. As noted above, the Zarqa aquifer begins at approximately 720 to 750 m of depth. The depth of each well is shown in Table 10.

TABLE 10
Depth of Kafrein Wells

Well	Depth
Kafrein Well # 12	620 m
Kafrein Well # 11	700 m
Kafrein Well # 4A	570 m

The major sources of water from a well drilled in a confined aquifer are: (1) water moving through the aquifer toward the well, (2) water forced from the aquifer by compaction caused by the weight of overlying sediments, (3) water expansion resulting from reduced pressures in the aquifer, and (4) water forced from surrounding aquicludes by compaction. (Driscoll 1987). When precipitation is inadequate to compensate for discharges from an aquifer or when heavy pumping takes place, the water level in an aquifer gradually falls over time. Although groundwater is a renewable resource, it can be temporarily depleted if good groundwater practices are not observed. Good groundwater management requires adequate information on the volume of water in storage and how this volume varies with time. Data on groundwater storage are obtained by periodic measurements of the depth to water (or the height of the watertable surface) from some reference point.

The WAJ currently does not have historical data on groundwater storage and pumping in the Kornub aquifer in the Kafrein region; they do, however, have a conceptual plan for monitoring the watertable in the area for changes. The WAJ should be encouraged to install this monitoring network through the Water Study Department and Well Committee. This monitoring program will help provide data on the recharge capabilities of the Kornub aquifer located near the Kafrein wells.

– Archeological Considerations

There are no known visible archeological ruins at this site. In general, construction personnel should use caution during any excavation works associated with implementation of this design. An archeologist will be retained to conduct an archeological survey at the site and will propose adequate measures for mitigating negative impacts to ensure that the project meets provisions of Antiquities Law No. 21, 1988, especially Articles 6, 13, 14, 15, 16 and 29.

Chapter 5
Fast-Track Project Implementation Plan

Each spring pumping station is frequently shut down during the dry season due to poor water quality. As a result, the WAJ and local water users are strongly urging installation of treatment facilities that will allow delivery of adequate water supplies during the next dry season which starts in May 1998. This chapter includes a general discussion of the priority order of site installations and the fast-track schedule necessary to complete installation by May. This chapter also includes a discussion of the budget and contracting mechanisms necessary to accomplish site preparation, installation, and start-up of the package WTPs.

5.1 Priority of Site Installations

WAJ engineers and water quality staff have prioritized the water resources that are in critical need of quality treatment as follows:

Priority	Site
1	Wadi Sir Spring
2	Qairawan Spring
3	Qantara Spring
4	Deek/Teis Spring
5	Kafrein Wells

Wadi Sir is the largest of the springs, producing more than twice as much water as any of the others. It is located in an urban area and serves 70,000 residents including patients and staff in the Al Hussein Medical City, as well as three other villages. As a result, it is considered the top priority among critical water resources in need of treatment.

The Qairawan spring is also located in an urban area and serves water users in the city of Jerash and surrounding areas. It is the second largest spring in need of quality treatment, and as a result, is listed second in priority.

Qantara and Deek/Teis reservoirs provide similar volumes of water. The Deek/Teis system is composed of two springs, and only the Deek spring becomes contamined during the dry season. The Teis spring is still able to produce acceptable water. In ranking the springs for urgent attention, the Qantara water resource has higher priority than the Deek/Teis system, since the former produces no water at all when the spring is shut down due to contamination.

Over the next five years, several new hotels are expected to be constructed and operating near the eastern coast of the Dead Sea. The adjacent communities of Suweimeh, Al-Ramah, and Jofa are likely to expand as a result of this new development. The Kafrein water source is several kilometers away from the three communities and the hotel sites. This site is considered by the WAJ to have a lower priority than the springs, since no distribution system exists and because the springs have been fully functioning in the past with established service populations who rely on them for water.

5.2 Milestone Schedule

A project schedule is given below. It indicates important milestones which must be met to achieve installation and operation requirements at each priority site in accordance with WAJ's desired schedule.

Project Milestone Schedule *

Nov. 1:	Assessment begins
Nov. 20:	Approval for limited procurement among water equipment vendors received from USAID
Nov. 22:	Draft Assessment Report to USAID and WAJ
Dec. 5:	Tender documents to vendor
Dec. 9:	Report approval from USAID/WAJ
Dec. 15:	Responses due from vendors
Dec. 22:	Select vendor to begin equipment fabrication
Jan. 1:	Begin Kafrein design
Jan. 10:	USAID finalizes contract with construction contractor who will carry the equipment vendor as a subcontractor
Jan. 15:	Begin equipment fabrication
Jan. 15:	Kafrein land acquisition finalized - WAJ
Jan. 30:	Construction contractor begins site preparation
March 15:	Kafrein design completed - drawings and specs
April 15:	Equipment shipped to Jordan
May 15:	Clear customs and transport equipment to site
May 31:	Start installing equipment at first site (Wadi Sir)
July 31:	Installation completed/start of O&M period
Jan. 31:	Completion of O&M period and Phase I of project

* schedule as of December 31, 1997

5.3 Contracting Mechanism

USAID and WAJ have determined that a design-build approach is the most appropriate mechanism to complete the design, fabrication, shipping, construction, installation, start-up, and operation of water treatment units at the four priority springs. A primary advantage of a design-build process is that coupling design with construction can condense the total life of the project. In addition, the contractor and designer can work together to maximize efficiency and identify methods that can potentially lead to lower costs for the client.

Under the design-build approach, consultants from the Environmental Health Project (EHP) will manage the development and installation of water package treatment units at the four priority sites and develop a design for the Kafrein water supply system. Plans for the Kafrein system will include the piping system from three wells to the treatment unit and design of the treatment unit with appropriate water storage facilities. Given the urgent need to install the WTPs before the next dry season and the limited time to fabricate and ship the units, it will not be possible to develop formal tender documents to procure the WTPs and the construction work through standard USAID procurement procedures. Instead, USAID has elected to follow procurement regulations for urgent and compelling needs which waive the requirement to conduct a formal competition. A limited competition has been conducted among U.S.-based package treatment plant suppliers. Each vendor was provided with criteria for selection and technical information including site plans and water quality information. A vendor has been identified based on the evaluation of technical and financial tenders, and is in the process of being selected. The equipment procurement is expected to be approximately $2 million.

USAID has identified a U.S. construction contractor with experience in Jordan to perform site preparation and construction modifications necessary to install the treatment units at the existing springs and pump station locations. To promote fast-track project implementation and ensure coordination of fabrication, shipping, and site preparation efforts, USAID will contract with the construction contractor in a manner which requires the construction contractor to procure the treatment units. Under this design-build arrangement, the designer/manager, constructor, and fabricator can work together in an efficient manner to accomplish the project in the shortest possible timeframe. The combined contract for construction services and the limited WTP procurement is expected to cost approximately $3.4 million. For a breakdown of these costs by site, see the budget in Section 5.4.

As the manager of the design-build process, EHP will work with the construction contractor to expedite the fabrication, shipment, installation, and start-up of the package treatment plant equipment. Working with the manufacturer, the construction contractor will provide the warranty for the equipment as well as training in operation and maintenance.

5.4 Budget

The estimated budget for the design-build project (as of December 31, 1997) is shown below. It is based on the WTP equipment proposal submitted by Smith and Loveless. Estimates for site civil, mechanical, and electrical work are based on figures obtained from the Morganti Group, a U.S. contractor, operating in Jordan. This budget could increase because of unforeseen civil, electrical, and mechanical modifications encountered during construction.

I.	Engineering Technical Assistance for Part I Design of the Kafrein water supply and treatment system	$416,100
II.	Wadi Sir Spring	
	Package Treatment Plant Equipment	$707,126
	Construction Services	$278,000
	Subtotal II	$985,126
III.	Qairawan Spring	
	Package Treatment Plant Equipment	$353,563
	Construction Services	$302,000
	Subtotal III	$655,563
IV.	Qantara Spring	
	Package Treatment Plant Equipment	$353,563
	Construction Services	$305,000
	Subtotal IV	$658,563
V.	Deek/Teis Spring	
	Package Treatment Plant Equipment	$353,563
	Construction Services	$271,000
	Subtotal V	$624,563
VI.	Spare Parts, Shipping, O&M Training, Pumps and Air Compressors for all 4 priority sites	
	Spare Parts	$42,460
	Shipping	$62,510
	O&M Training	$73,000
	Pumps and Compressors	$281,108
	Subtotal VI	$459,078
Total Draft Budget		**$3,798,993**

5.5 Project Schedule

A projected schedule for this work is shown in Figure 5-1.

Figure 5-1
Draft Schedule for Rehabilitation of Priority Wells and Springs

Chapter 6
Recommended Issues to Be Addressed

In addition to the technical and environmental considerations associated with installation of the treatment units, several other issues should be considered. They include a water resource protection program, site-specific technical recommendations, operational recommendations, and the financial sustainability of operating the treatment units. This chapter includes a brief discussion of these issues.

6.1 Water Resource Protection Program

The presence of coliform and nitrate in groundwater sources is cause for concern, indicating that the groundwater is being infiltrated directly or indirectly from a contaminated surface water source. Typical contamination sources include leakage from cesspits, barnyards, sewage lagoons, agricultural chemicals in soils, and animal wastes. Unfortunately, contamination of groundwater is more serious than surface water pollution since groundwater moves more slowly and has less self-cleansing capacity. In contrast to rapidly moving freshwater streams, underground water moves very slowly and does not have ready access to oxygen supplies. Therefore, once contaminated, groundwater tends to remain in that condition and ceases to be a safe source of water supply until contamination is completely flushed out, which can take years or decades. Moreover, contamination of groundwater is difficult to detect in a timely manner and requires special expertise to predict the path and rate of contaminant movement.

Because Jordan relies heavily on groundwater for drinking water, intensive efforts should be made to prevent its contamination from occurring. Land-use planning and watershed protection can play major roles in protecting groundwater quality, and thus the water supplied from these sources. While installation of package treatment units will improve drinking water quality in the short term, a more important measure is to safeguard drinking water sources over the long term by taking protective action. A comprehensive investigation and identification of sources contributing to contamination of the springs should be undertaken.

As an example, in the case of Qantara, subsurface contamination from cesspits and possibly surface contamination from disposal of sewage in wadis in the upper watershed are believed to be impacting the quality of this spring. To help mitigate such problems, careful consideration should be given to (1) finding ways to isolate these municipal wastes from the groundwater, (2) developing an action plan to mitigate the negative effects of municipal waste, and (3) prioritizing the actions to be taken to address the pollution. Measures taken now to protect the springs are expected to be much more cost effective in the long run than the annual recurring costs associated with operation and maintenance of additional water treatment facilities. To help identify sources contributing to contamination of the springs, WAJ laboratories should be provided with the facilities and staff training to determine concentrations of cryptosporidium oocysts and giardia cysts.

6.2 Site-Specific Technical Recommendations

There are several operation and maintenance measures that, if undertaken, would help promote safer drinking water from the springs. The vulnerability of temporarily stored water and the integrity of the water reservoir structures at each of the springs should be regularly evaluated by WAJ water quality engineers. Many of the reservoirs at the springs are open to the environment, thus exposing the finish water to possible contamination. For example, the pump suction piping at the Wadi Sir pump station was installed by breaking through the reservoirs walls. These suction pipe connections were never sealed, which exposes the finish water to the environment. At the Qantara pump station, vegetation was observed in the finish water reservoir. At the Deek spring, animal feces were observed in the concrete spring box. At Qairawan, the fine stones used to filter the water at the spring bed were dispersed. Each of these situations could be corrected by the implementation of a formal maintenance program at each site.

6.3 Operational Recommendations

WAJ should commit two full-time employees to operate, maintain, monitor and manage each treatment facility. Operators should participate in training which will be conducted intermittently for six months following installation of the WTPs.

While the operation and maintenance responsibilities vary according to the type of filtration technology selected, efforts will be made to select technologies which require the least amount of operational management and monitoring. Regular maintenance of the facilities, including changing filters, oil, fuses, adding required chemicals, cleaning filters, installing spare parts, and keeping an inventory of all parts and consumables used and needed will be the responsibility of the WAJ. In addition, sudden changes in spring flow, spring turbidity, and electrical power fluctuations can impact the integrity of the treatment process and will require close observation by operators throughout the life of the treatment facilities.

6.4 Financial Sustainability

A major consideration when identifying technologies suitable for host-country recipients is the level of service which can be sustained. Costs associated with operating and maintaining a specific level of service should be reflected in tariffs. In this way, tariffs are linked with service delivery, and local utilities then have the ability to obtain revenues to cover operation and maintenance costs.

Costs associated with operating and maintaining the package treatment plants should be reflected in tariffs levied by local utilities. In fact, to be fully responsive to the WAJ request for installation of four package treatment plants, a broader effort than this current report should be made to identify and incorporate these costs into the context of the existing cost-recovery systems. Such an effort would include reviewing the financial viability of the treatment units (including depreciation and replacement costs) and examining the capacity of the local water and wastewater institutions to recover costs and make investment decisions. Currently, USAID is supporting a study under the FORWARD project to help determine the real cost of water and identify specific tariff issues that must be addressed.

Appendix A

Contacts

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Appendix A
(Continued)

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Site layouts for Wadi Sir and other springs provided by Ratib Shbib.

Information on water supply projects for the eastern shore of the Dead Sea provided by Jahad Jamous.

Pump testing data for Kafrein Wells provided by Jhad Jamous.

Information regarding five contaminated spring/wells provided by Dr. Marjorie Shovlin.

Appendix B

WQIC Water Quality Report Data